

# OPTICAL EMISSION SPECTROSCOPY STUDIES OF THE SPALLATION NEUTRON SOURCE (SNS) H<sup>-</sup> ION SOURCE\*

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## Abstract

The SNS H<sup>-</sup> ion source relies on Cs enhancement to produce the persistent, high current beam for the 1-MW operation of the facility. Optical emission spectroscopy is used as plasma diagnostics to detect and monitor the Cs and impurities in the system in order to optimize the ion source conditioning and cesiation processes. This technique is also used in an effort to find precursors of failures of the ion source antenna coating.

## INTRODUCTION

A Cs enhanced, RF-driven, multi-cusp ion source feeds the Spallation Neutron Source (SNS) accelerator with a 65 keV H<sup>-</sup> beam at 60 Hz with a pulse length of ~1.0 ms. Fig. 1 is a schematic view of the ion source showing the main functional components. The high-power hydrogen plasma is generated by pulsed, high-power 2-MHz RF (up to ~80 kW) assisted by a continuous, low-power 13.56-MHz RF (~300 W) driven through a 2.5-turn porcelain coated antenna. Multi-cusp magnetic fields provide plasma confinement in radial and backward directions. The filter magnets generate a ~300 G transverse field, which allows only cool plasma to drift toward the outlet aperture. Cartridges containing a mixture of Cs<sub>2</sub>CrO<sub>4</sub> and St101 getter are embedded in the Cs collar, which can be heated to release elemental Cs. At the end of the Cs collar is the Mo cone which greatly facilitates the H<sup>-</sup> production when covered with a fractional monolayer of Cs. The dumping magnets generate ~1.6 kG transverse field, which deflects the co-extracted electrons onto the e-dump electrode while the negative ions are extracted [1].

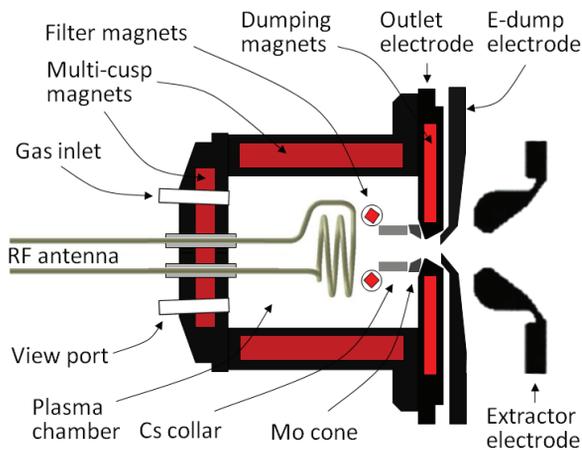


Figure 1: A schematic view of the SNS H<sup>-</sup> ion source.

Having the optimum mono-layer of Cs on the Mo ion converter surface near the ion source outlet is essential for achieving high current, persistent H<sup>-</sup> beams with the SNS ion source. Detecting and monitoring the Cs and other impurities in the ion source plasma are important to understand and optimize our experimentally established procedure for the ion source conditioning and cesiation. In addition, observing certain plasma impurities could reveal a precursor for failures of the RF antenna coating. In this work, a powerful plasma diagnostics technique - optical emission spectroscopy [2] is employed in identifying and tracking the particle population density in the ion source plasma. The preliminary results are discussed here.

## EXPERIMENTAL SEUTP

As shown in Fig. 1, a sapphire view port on the ion source back flange provides a window to the plasma lights. The lights are focused with a collimating lens and transmitted through an optical fiber to a Jaz model spectrometer [3]. Our Jaz spectrometer has two channels; the first channel was optimized for 300 nm wavelength and covers a range of 200-850 nm, the second one was optimized for 750 nm covering 500-1100 nm. Both channels have the same optical resolution of 1.3 nm with high sensitivity in their respective range. A computer connected to the spectrometer via USB or Ethernet handles control and data acquisition.

## THE ION SOURCE CONDITIONING AND CESIATION PROCESSES

Figure 2 illustrates the SNS conditioning and cesiation processes for a newly installed ion source. Once the continuous 13.56-MHz RF plasma is ignited, the 2-MHz

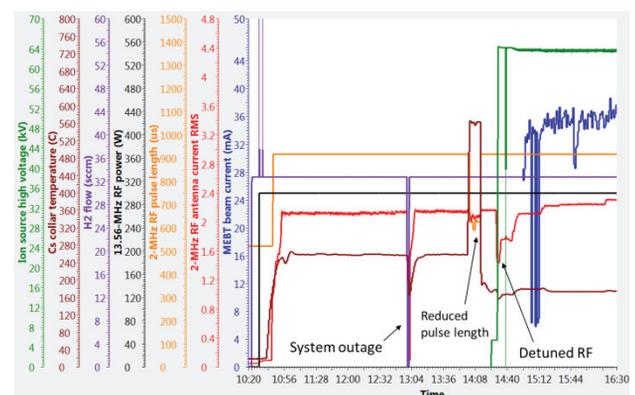


Figure 2: Conditioning and cesiation processes for a newly installed ion source.

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RF is brought up to high power (represented by the antenna current rms value measured in oscilloscope channel) and full duty-factor for routine operational level. The source is conditioned with the high power plasma for ~3 hours to sputter clean and degas the system. At the same time an external heater maintains the Cs collar temperature near 250 °C to boost the degassing of the Cs<sub>2</sub>CrO<sub>4</sub> and St101 getter mixture. After ~3 hours, the Cs collar temperature is elevated to ~550 °C for 10-15 minutes to cesiate the ion source. After the cesiation, the ion source high voltage is ramped up with a detuned 2-MHz RF to reduce the beam losses and the associated sparking in the downstream low energy beam transport section. When the ion source high voltage reaches its nominal value (-65 kV), the 2-MHz RF tune is restored for high power, and the beam is tuned for maximum transmission.

### IMPURITIES AND THE CESIUM

In the experiments, the Jaz spectrometer is triggered by the 2-MHz RF timing pulse and the integration time is set for 2.0 ms to include the entire RF pulse length.

Figure 3 shows a spectrum of the plasma lights in the very early stage of the ion source plasma conditioning. In addition to the atomic hydrogen Balmer series lines and the molecular hydrogen emission bands, several other strong lines or bands are observed in the spectrometer's wavelength range. O and OH are likely from dissociation of H<sub>2</sub>O. This is consistent with the residual gas analyses in the low energy beam transport chamber, which H<sub>2</sub>O to be the dominant impurity in the system. Overlapping with a H<sub>2</sub> band, the line at 589 nm could be the emission of sodium sputtered off the porcelain coating of the RF antenna. The Cs emission line at 852 nm is barely seen at this stage of the plasma conditioning.

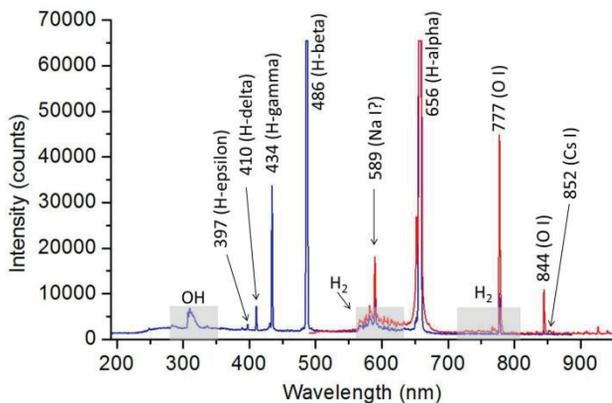


Figure 3: Spectrum of the plasma emission lights in the early stage of the ion source conditioning.

Figure 4 is a spectrum taken at the end of the 3-hour plasma conditioning just before the cesiation. The initially intense lines from O and OH have faded down to the level of the nearby background. The H<sub>2</sub> bands appear stronger than in Fig. 3. The Cs line at 852 nm has become obvious.

Apparently the Cs cartridges already emit some Cs at 250 °C before the intended cesiation process has started.

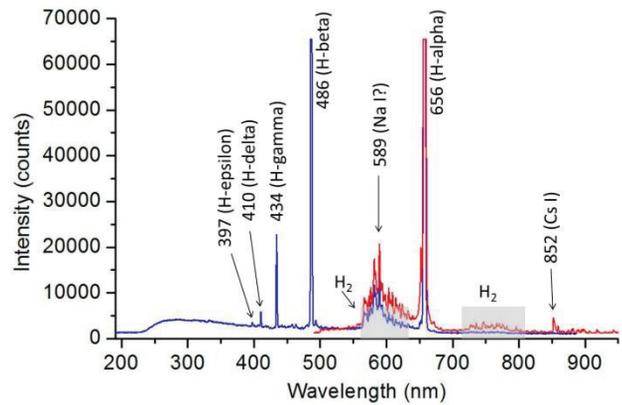


Figure 4: Spectrum of the plasma emission lights at the end of the 3-hour ion source conditioning.

Figure 5 shows the spectrum at the end of raising the temperature to ~550 °C to release Cs. This significantly strengthened the Cs line at 852 nm, and elevates another Cs line at 894 nm above the background. This confirms successful release of Cs during our cesiation process.

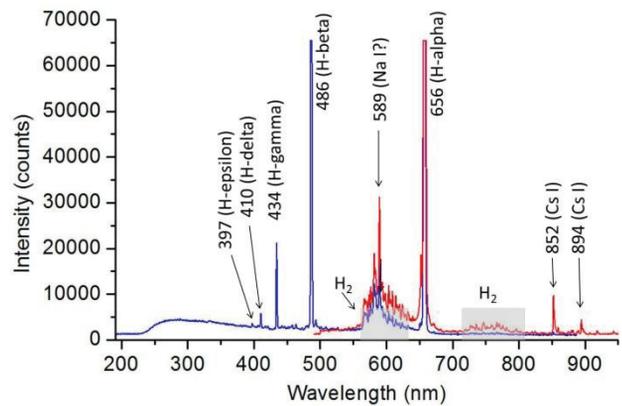


Figure 5: Spectrum of the plasma emission lights just after the cesiation process is terminated

Figure 6 shows the intensity of the Cs 852 nm line and some impurity lines along with the H-delta (410 nm) and H-gamma (434 nm) lines as a function of time. The H-alpha (656nm) and H-beta (486 nm) lines were saturated and not shown in the figure. The impurity lines decayed down within about 2 hours of plasma conditioning. The Cs line continually grew during the plasma conditioning when the Cs collar temperature was maintained at ~250 °C. Elevating the collar temperature to 550 °C rapidly released a burst of Cs into the system. In order to illustrate the dynamics of the Cs population density in the plasma, Figure 7 shows a plot of the intensity ratio of the Cs line and the H-delta line. This ratio factors out changes of the RF power and the RF tune. The Cs in the plasma appears to decay with a time constant of ~2 hours followed by a much longer, slower decay. Figure 8 is a

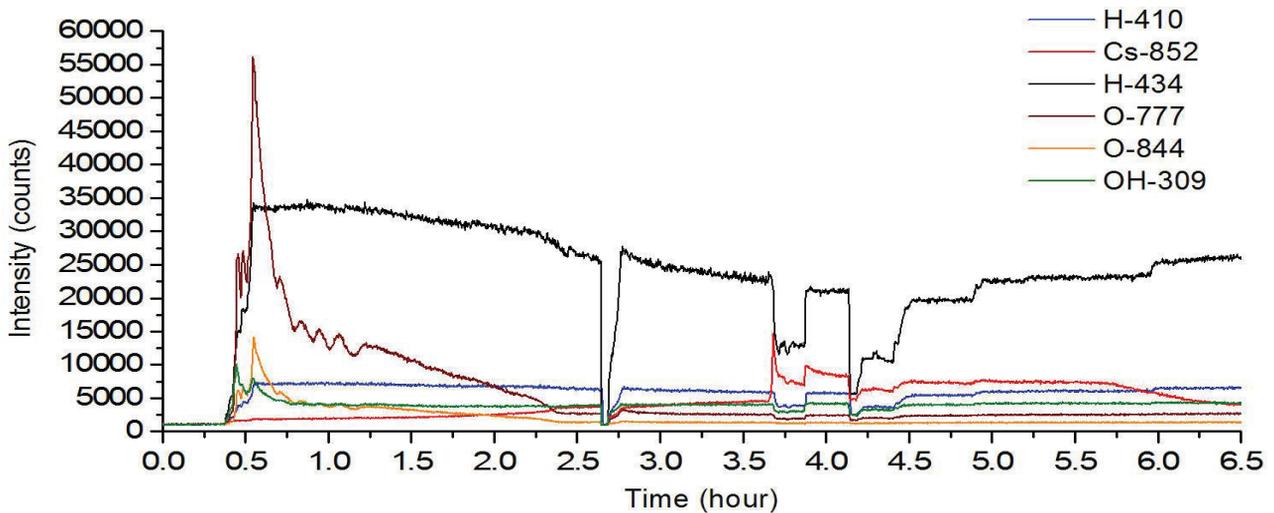


Figure 6: Intensity evolution of the known major spectral lines of the ion source plasma emission lights.

spectrum taken after 6 weeks of persistent high current operation of an ion source.

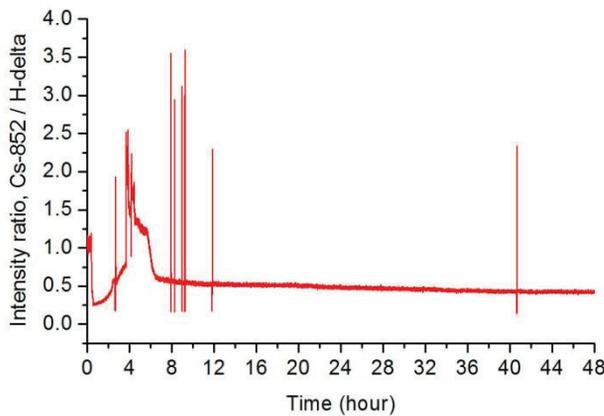


Figure 7: Intensity ratio of the Cs-852 line and the H-410 line over the 48 hours of the ion source start-up.

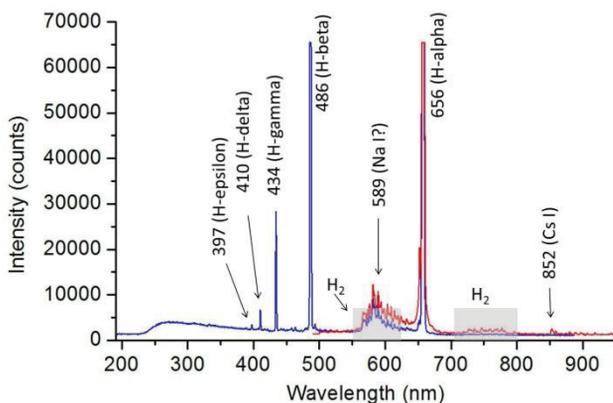


Figure 8: Spectrum of the plasma emission lights after six weeks of operation of an ion source.

### PRECURSOR FOR ANTENNA FAILURES

The likely Na line at 589 nm has long been considered as an indication of sputtering the porcelain coating on the RF antenna. Unfortunately its wavelength overlaps with a H<sub>2</sub> band, which appears to grow during conditioning. Figure 9 shows the evolution of the 589 nm line intensity during conditioning, which differs greatly from the Balmer lines. A possible explanation is the sputtering of Na by impurities, which fade away over the first hour, while the increasing purity lets the H<sub>2</sub> band grow. However, further studies are needed.

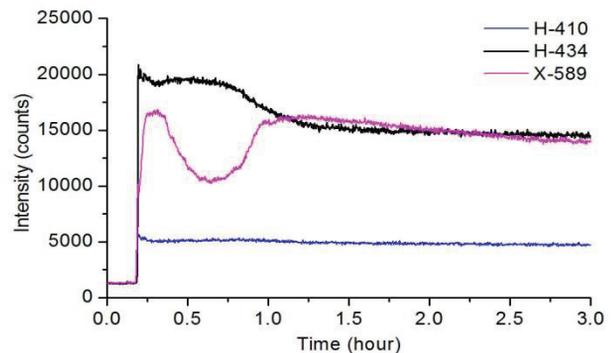


Figure 9: Typical evolution pattern of the 589 nm peak.

### ACKNOWLEDGMENT

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